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PENSOFT

# Mammal inventory in the Mongolian Gobi, with the southeasternmost documented record of the Snow Leopard, *Panthera uncia* (Schreber, 1775), in the country

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**Abstract**
Studies on mammal diversity and distribution are an important source to develop conservation and management strategies. The area located in southern Mongolia, encompassing the Alashan Plateau Semi-Desert and the Eastern Gobi Desert-Steppe ecoregions, is considered strategic for the conservation of threatened species. We surveyed the non-volant mammals in the Small Gobi-A Strictly Protected Area (SPA) and its surroundings, by using camera trapping, live trapping, and occasional sightings. We recorded 18 mammal species belonging to 9 families and 6 orders. Among them, 4 are globally threatened or near-threatened, 2 are included in the CITES Appendix I, and 2 are listed in the Appendix II. Moreover, we provide the southeasternmost record for the Snow Leopard (*Panthera uncia*) in Mongolia, supported by photographic evidence. Our study highlights the importance of this protected area to preserve rare, threatened, and elusive species.

**Keywords**
Camera trapping, desert, live trapping, mammal checklist, species richness, threatened species.

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## Introduction

Deserts cover 17% of the world's land mass, hosting a high biodiversity (Ward 2010), which includes some of the most endangered species in the world (Durant et al. 2012). A larger effort is needed to improve the knowledge on the desert ecosystem, as it would benefit biodiversity conservation at a global level. Mongolia is among the world's largest landlocked countries and approximately a third of its surface is covered by the Gobi Desert (John et al. 2009, Lamchin et al. 2016). The Mongolian desert hosts several globally threatened and charismatic species of mammals, such as the Wild Bactrian Camel (*Camelus bactrianus* Linnaeus, 1758), the Saiga Antelope (*Saiga*

*tatarica* (Linnaeus, 1766)), the Snow Leopard (*Panthera uncia* (Schreber, 1775)), and the Goitered Gazelle (*Gazella subgutturosa* (Güldenstädt, 1780)).

The Mongolian mammal community is diverse, with 128 native species (Clark et al. 2006, Murdoch et al. 2006) belonging to 7 orders, as follows: Carnivora, Cetartiodactyla, Chiroptera, Eulipotyphla, Lagomorpha, Perissodactyla, and Rodentia (>60 species) (Clark et al. 2006, Murdoch et al. 2006). Because the Mongolian faunal inventories are hardly available to a large audience (Lebedev et al. 2016), with data often derived from broader studies (Murdoch et al. 2006), an inventory of the mammal species would help fill the so-called Wallacean shortfall (Whittaker et al. 2005, Lomolino et al. 2010).

Camera trapping has recently become a widely used tool in wildlife research as it enables to gather data on the majority of the medium-large sized mammals occurring in the sampled area, including extremely elusive species (Rowcliffe and Carbone 2008, Burton et al. 2015).

To assess the presence of small mammals, which are rarely detected by camera traps and are prone to misidentification via photos (Potter et al. 2018), we chose to use live traps. Live trapping is considered a reliable method to detect a variety of small mammal species and thus observe in detail morphological features of the trapped species (Flowerdew et al. 2004).

Given the lack of information on mammals in this region, there is an urgent need to generate an updated list of species (Murdoch et al. 2006, Lebedev et al. 2016). Our study reports the first inventory of non-volant mammal species obtained through camera trapping, live trapping, and direct observations in 2 areas within the South Gobi province, Mongolia.

Through a qualitative analysis, we made some considerations on the effectiveness of the environment protection in the Small Gobi-A, and we added relevant information to the ongoing understanding of ecological patterns and distribution of the species involved.

## Methods

**Study area.** The study was carried in the South Gobi province, Mongolia (Fig. 1), covering approximately 1000 km² with elevations ranging between 965 and 1809 m a.s.l. We performed a survey in the Small Gobi-A Strictly Protected Area (42°39′N, 105°79′E, datum WGS84; area ca 11,500 km²), and in a boundary area (BA), a non-protected area located in the Bayan Ovoo district (42°58′N, 106°07′E, datum WGS84; area ca 6000 km²).

The southern Mongolian Gobi is part of the Central Asian dryland region and forms the easternmost part of the Old World's desert belt (Wehrden et al. 2009). The climate of the region is semi-arid and highly continental with a very short growing season due to the long cold winters (January mean, 15–20 °C) and short hot summers (July mean, 20–25 °C) (Weischet and Endlicher 2000). Hence, levels of annual rainfall range from 100 mm/a to as low as approximately 33 mm/a (Wehrden et al. 2009).

In the study area, the vegetation is sparse and dominated by desert-steppe and semi-desert plant communities, principally *Artemisia* spp. in the family Asteracea, *Allium* L. in the family Amarillydaceae, *Stipa* L. in the family Poaceae, and *Anabasis brevifolia* C.A.Mey in the family Amaranthaceae. The plant community of the desert areas is dominated by Chenopodiaceae, such as *Haloxylon ammodendron* (C.A.Mey.) Bunge ex Fenzl and *Anabasis brevifolia*, and also Asteraceae, such as *Artemisia* L. and *Ajania* P. P. Poljakov. Poaceae, such as *Stipa* and *Ptilagrostis* Griseb., dominate the steppe areas. Tree species, such as *Haloxylon ammodendron*, *Ulmus pumila* L., and *Populus euphratica* Oliv., are rare and restricted to river valleys and large basins (Wehrden et al. 2009).

The Small Gobi-A SPA is characterized by dry flatland, dunes, and mountainous habitats, while the BA is characterized by flat, rocky or sandy, and dry habitats. Both areas are intermixed by desert and xeric shrubland patches. While the Small Gobi-A SPA is a strictly pristine area, in the BA there is no restriction on livestock, and mineral extraction activity is allowed. Moreover, for the Bayan Ovoo District, there is a human population estimated at 1,686 inhabitants (NSO 2018) with a density of 0.15 inhabitant/km² (NSO 2018).

Considering globally threatened species (IUCN 2018), the central Alashan Plateau Semi-Desert Ecoregion represents a refuge for such species as the Goitered Gazelle or the Snow Leopard and the southeasternmost area for the distribution of these species in Mongolia. Furthermore, the Mongolian Gobi supports the largest remaining population of the Asiatic Wild Ass (*Equus hemionus* Pallas, 1775) which has been globally assessed as Near Threatened (IUCN 2018).

**Data collection.** Our aim was to collect the most occurrence data of non-volant mammal species occurring in the study area. We used an integrated approach combining different sampling techniques (i.e. camera trapping, live trapping, and occasional sightings). We used camera traps to asses occurrences for medium-sized and large mammals (Rovero and Marshall 2009, Rovero et al. 2013, Rovero and Zimmermann 2016), while live trapping was employed to detect small mammals (i.e. < 1 kg, sensu Wilson and Reeder 2005). In addition, we also included records made by direct sightings. We identified the conservation status following the IUCN Red List (IUCN 2018), and the Mongolian Red List of Mammals (Clark et al. 2006; Table 1).

**Camera traps.** Camera trap sampling was designed to be as much representative as possible of the different habitats occurring in the study area. Based on the interaction between 2 topographic variables (i.e., elevation ≥1100 m a.s.l. and slope ≥20%) we used ArcGIS 10.3 (Dilts 2015) to overlay a grid of 3 × 3 km cells (9 km²) and identify potentially suitable areas for ungulates and

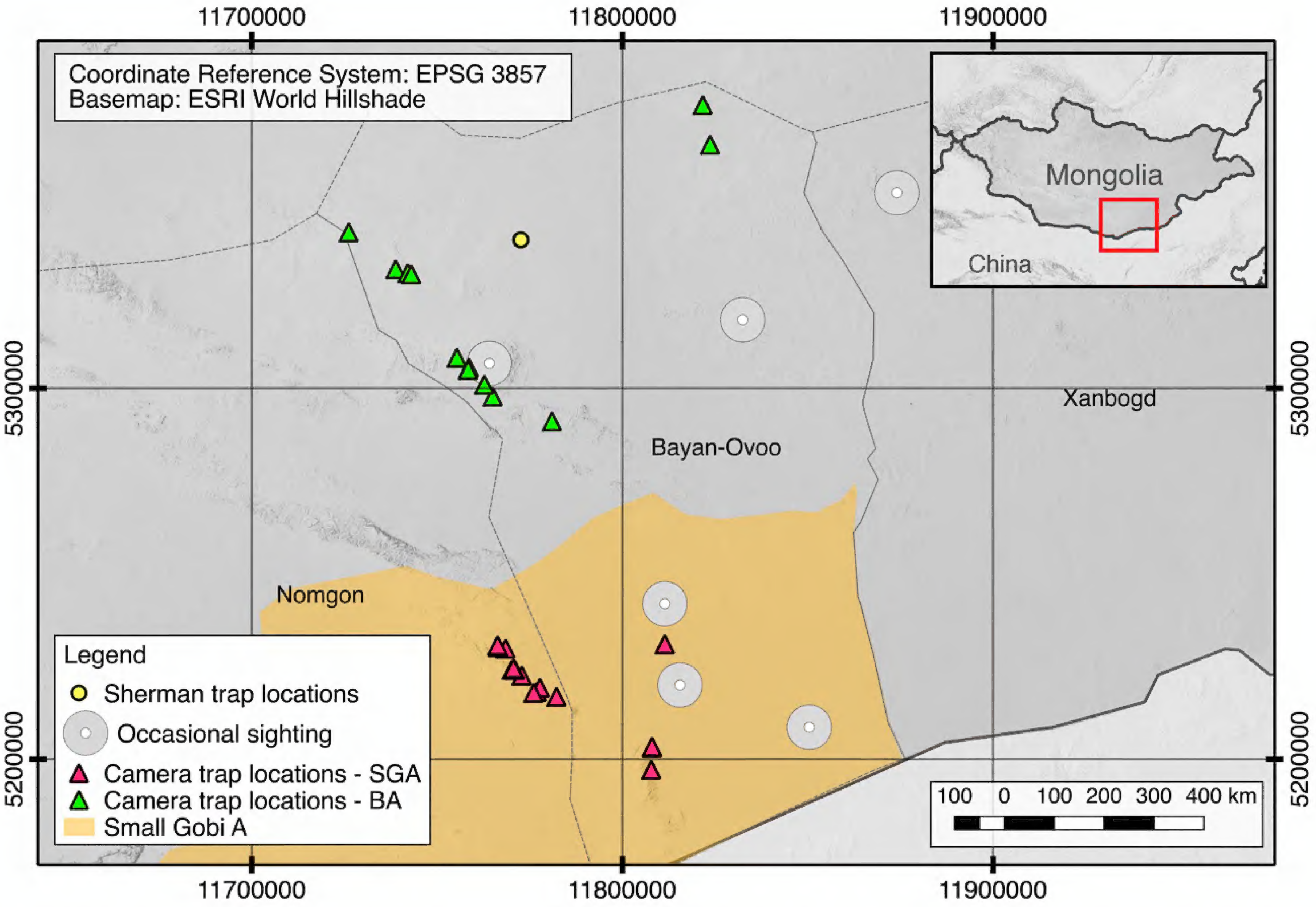


**Figure 1.** Map of the study area. Small Gobi-A Strictly Protected Area. Sherman trap locations: traps distributed along a linear transect (10 m distant). Camera trap locations: Camera traps located in the Small Gobi-A Strictly Protected Area (SGA) and in the Boundary area (BA).

large carnivores encompassing the study area.

Between May and September 2017, we sampled 15 different sites by 15 sampling units (installed between 1460 to 1809 m a.s.l.) within the boundary area. At each sampling unit, we installed a single camera trap (model: Bushnell Nature View, Reconyx HC600 or Cuddeback Black Flash E3) with an average height of 50 cm above the ground (Tobler et al. 2008), maintaining a distance

**Table 1.** Species list of mammals detected in the Small Gobi-A Strictly Protected Area and its boundary area through the three methods used. Species were listed with their global and regional conservation status referring to the IUCN Red List (2018), the Mongolian Red List of Mammals (MRed List, Clark et al. 2006), and the Cites Appendices. IUCN and MRed List: Red List categories, as follows: VU = Vulnerable, LC = Least Concern, EN = Endangered, NT = Near Threatened. CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora code: App. I = species listed under CITES Appendix I, App. II = species listed under CITES Appendix II, NL = not listed.

| Order | Family | Scientific name | Common name | IUCN | MRed List | CITES |
|---|---|---|---|---|---|---|
| Carnivora | Canidae | *Vulpes corsac* (Linnaeus, 1768) | Corsac Fox | LC | NT | NL |
| | | *Vulpes vulpes* (Linnaeus, 1758) | Red Fox | LC | NT | NL |
| | Felidae | *Lynx lynx* (Linnaeus, 1758) | Eurasian Lynx | LC | EN | App. II |
| | | *Panthera uncia* (Schreber, 1775) | Snow Leopard | VU | EN | App. I |
| Cetartiodactyla | Bovidae | *Capra sibirica* (Pallas, 1776) | Siberian Ibex | LC | NT | NL |
| | | *Gazella subgutturosa* (Güldenstädt, 1780) | Goitered Gazelle | VU | VU | NL |
| | | *Ovis ammon* (Linnaeus, 1758) | Argali | NT | EN | App. II |
| | | *Procapra gutturosa* (Pallas, 1777) | Mongolian Gazelle | LC | EN | NL |
| Perissodactyla | Equidae | *Equus hemionus* (Pallas, 1775) | Asiatic Wild Ass | NT | EN | App. I |
| Eulipotyphla | Erinaceidae | *Hemiechinus auritus* (Gmelin, 1770) | Long-eared Hedgehog | LC | LC | NL |
| Lagomorpha | Leporidae | *Lepus tolai* (Pallas, 1778) | Tolai Hare | LC | LC | NL |
| Rodentia | Dipodidae | *Allactaga bullata* (Allen, 1925) | Gobi Jerboa | LC | LC | NL |
| | | *Dipus sagitta* (Pallas, 1773) | Northern Three-toed Jerboa | LC | LC | NL |
| | Cricetidae | *Cricetulus migratorius* (Pallas, 1773) | Gray Dwarf Hamster | LC | NT | NL |
| | | *Meriones meridianus* (Pallas, 1773) | Mid-day Gerbil | LC | LC | NL |
| | | *Meriones unguiculatus* (Milne-Edwards, 1867) | Mongolian Gerbil | LC | LC | NL |
| | | *Phodopus roborovskii* (Satunin, 1903) | Desert Hamster | LC | LC | NL |
| | Sciuridae | *Spermophilus pallidicauda* (Satunin, 1903) | Pallid Ground Squirrel | LC | LC | NL |

of 1–4 km between contiguous sites. We set the cameras on carnivores marking points, forced passages, in ridges and at the bottom of valleys and water sources (e.g. front or ponds), hence set on rocks at a distance of approximately 4–5 m from the target trail.

The camera traps were left unattended for a minimum of 40–45 days. We identified all photographic records using the book by Batsaikhan (2014). The data were entered them into an Excel database with the camera location, date of capture, and date of download. We removed repeated captures, which clearly showed the same individual appearing during a continuous time period (O'Brien et al. 2003).

At the end of September 2017, we installed 24 sampling units (installed at 916–1427 m a.s.l.) in the Small Gobi-A SPA (Fig. 1), using the same design that was previously adopted outside of the protected area.

We analyzed the images from the cameras entering species identification and metadata using Wild.ID, dedicated open-access software (Bolger et al. 2011). The images were filtered for independent detection events; images of the same species taken within a span of 30 min were scored as a single event to avoid multiple scoring of the same individuals that represents a single detection event (Bolger et al. 2011).

**Live traps.** We conducted the live trapping survey in May and August 2017, using Sherman traps (PLFA, 7.62 × 8.89 × 22.86 cm). We set the traps 10 m apart from each other, with a maximum of 20 traps per transect; traps were baited with peanut butter, honey, and oats. We sexed and weighted live-trapped animals using a Pesola spring balance (precision: 0.05 g). Using a metal caliper (0.01 mm of accuracy), we measured the total length, tail length, head length, fibula-metatarsus, radio-ulna, third rear, and front phalanges. We then released the animals at the place of capture after being photographed. We identified species based on external morphological characters using identification keys (e.g. Smith et al. 2010, Darvish 2011, Batsaikhan 2014).

**Field observations.** With the objective of improving the species inventories obtained with camera traps and live traps, we opportunistically recorded mammal species observations in the study area. We recorded, during both daylight and night, any sighting made within the study area during the travels by car or by trekking. We recorded the presence and coordinates of both live individuals and carcasses (e.g. animals ran over by vehicles). Observations were identified using the field guide by Batsaikhan (2014).

**Data analysis.** Using the statistical program R (R Development Core Team, 2018), we analyzed the camera traps data calculating for each species the relative abundance index (RAI; O'Brien 2011, Sollmann et al. 2013), which represents the number of photographic events at which a species is trapped during the sampling and naïve occupancy (MacKenzie et al. 2002, MacKenzie and Nichols 2004). The naïve occupancy is considered as the number of sites positive to species presence to the total number of sites, which is a complementary index of abundance to the event rate (MacKenzie et al. 2002). Naïve occupancy value ranges from 0 to 1, when the value is closer to 1 a larger proportion of sites were occupied by the species (MacKenzie et al. 2002, Rovero and Zimmermann 2016). We determined the relative abundance index for every mammalian species using the following equation:

$$\mathrm{RAIsp}a = \text{events} * 100 \text{ camera trap nights/sampling effort}$$

Where RAIsp$a$ = relative abundance index for species '$a$'; events = number of independent records per species; 100 camera trap nights = unit of standardization to compare data with other studies; sampling effort = total amount of nights that the camera trap stations were working.

Finally, to assess the completeness of the sampling effort, we used a method recently introduced by Hsieh et al. (2016), which allows to compare species diversity across assemblages using rarefaction and extrapolation sampling curves. We used the iNEXT package (Hsieh et al. 2016) in R (R Development Core Team, 2018) to compute and compare species diversity among the Small Gobi-A SPA and its boundary area. In particular, we used sampling-unit-based incident data (i.e. detection events) to compute such curves.

## Results

We recorded 18 native mammal species in the Small Gobi-A SPA and BA using the combined methodologies. This number represents a high percentage of the species potentially occurring in the study area (Batsaikhan 2014). The species recorded belong to nine families: Felidae, Canidae, Bovidae, Equidae, Erinaceidae, Muridae, Dipodidae, Cricetidae, and Sciuridae. Bovidae was the most species-rich family with 4 species (Table 1). In total, 6 orders were recorded, representing 85.71% of the mammalian orders present in Mongolia.

Furthermore, rodents were the best represented order with 7 species (7/18; 38.9), followed by carnivores and cetartiodactyls represented by 4 species each (4/18; 22.2%). The remaining 3 orders, Eulipotyphla, Lagomorpha, and Perissodactyla, were each represented by a single species (1/18; 5.6%).

We set 39 camera traps stations in total, and 31 of them were functioning. We obtained 436 independent detection events during our survey which totaled of 1542 camera days (Table 2). An event is an instance of capture obtained by screening the original images acquired by a set interval of time between subsequent images.

We detected 9 wild mammal species belonging to 4 orders and 5 families with camera traps. Four species of Carnivora were recorded, followed by 3 species of Cetartiodactyla, 1 species of Lagomorpha, and 1 species of Perissodactyla. Most of the species detected belonged to Perissodactyla (282 independent events), followed

**Table 2.** Summary of the camera traps activity, in the Small Gobi-A Strictly Protected Area (SGA) and its boundary area (BA). Sampling Effort = number of trap-nights per number of cameras arrayed; Cameras placed = number of cameras displayed inside the protected area and its boundary area; Functioning Cameras = functioning cameras during the sampling period; Occupied Sites = sites with at least 1 wild animal detected by the camera; Total independent detection = sums of detections, with a minimum span of 30 minutes between two photos.

| Area | Sampling effort | Cameras placed | Functioning cameras | Occupied sites | Total independent detections |
|---|---|---|---|---|---|
| SGA | 732 | 24 | 21 | 17 | 375 |
| BA | 810 | 15 | 10 | 10 | 61 |

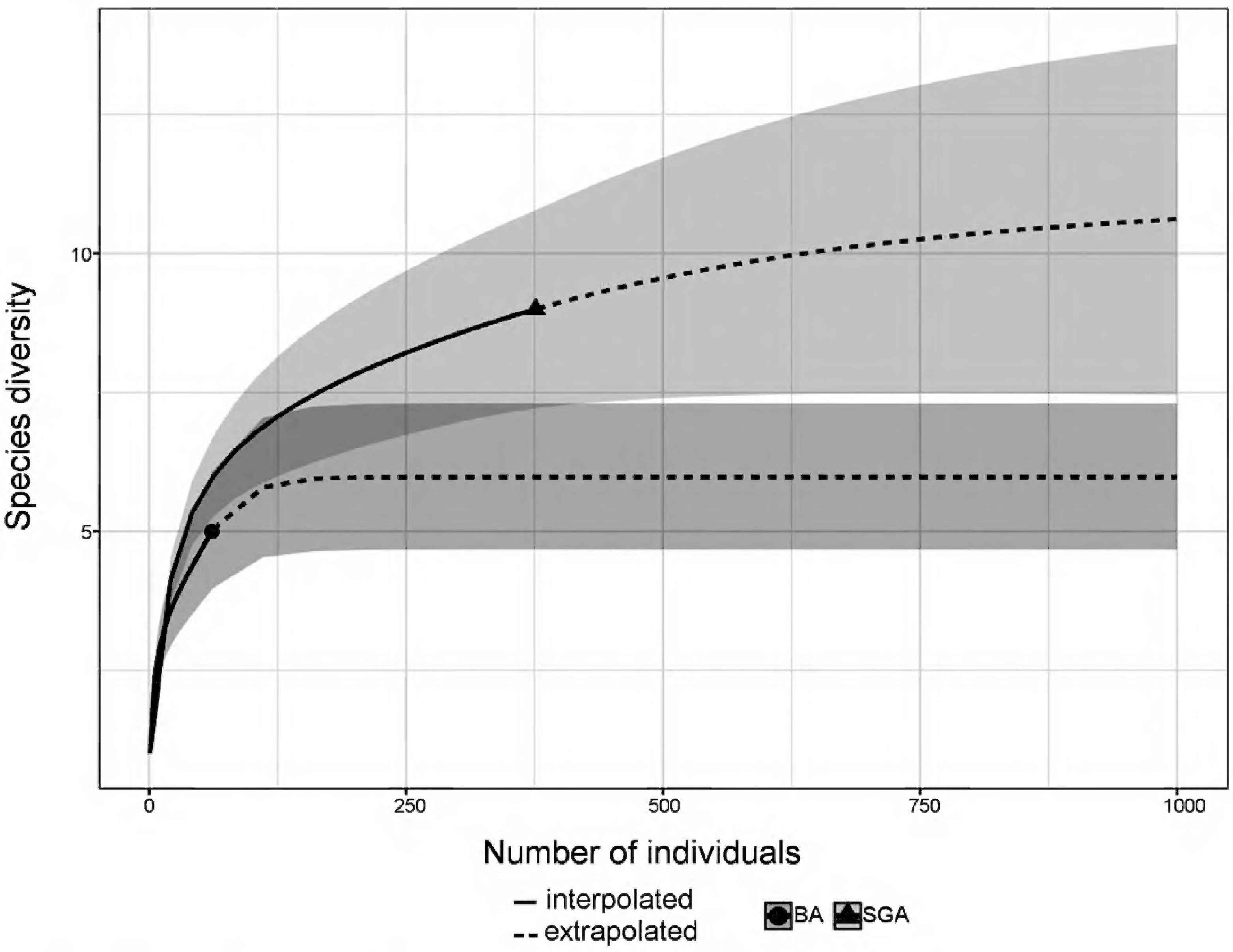


**Figure 2.** Sample-size-based rarefaction (solid line segment) and extrapolation (dotted line segments) sampling curves with 95% confidence intervals (shaded areas) for species richness in the Small Gobi-A (SGA) and its boundary area (BA). Data were referred to camera trap sampling. The solid dot/triangle represent the reference samples.

by Cetartiodactyla (80 independent events), Lagomorpha (40 events), and Carnivora (34 events). Most of the species detected with camera traps were locally or globally threatened ungulates (Table 1): the Asiatic Wild Ass (*Equus hemionus*; 282 events), the Siberian Ibex (*Capra sibirica* Pallas, 1776; 48 events), the Goitered Gazelle (*Gazella subgutturosa*; 26 events), the Argali (*Ovis ammon* Linnaeus, 1758; 6 events).

Among the carnivores, the most frequently detected species was the Red Fox (*Vulpes vulpes* Linnaeus, 1758; 30 events), followed by the Eurasian Lynx (*Lynx lynx* Linnaeus, 1758; 2 events), the Snow Leopard (*Panthera uncia*; 1 event), and the Corsac Fox (*Vulpes corsac* Linnaeus, 1768; 1 event).

We recorded 8 mammal species in the Small Gobi-A SPA using camera traps and 5 species in the boundary area (Fig. 3; Table 3). The 282 independent detection events of Asiatic Wild Ass is remarkable, as this species is rarely recorded (Kaczensky et al. 2013).

Unexpectedly, we detected the Snow Leopard, which is a new record for the area. The nearest record is approximately 50 km to the west (unpublished data by Small Gobi-A Stricly Protected Area administration). It was photographed at an elevation of 1350 m a.s.l., in a forced passage laying on a cliff bottom, in a rocky rugged area where the highest elevation was up to 1500 m a.s.l.

Also, we obtained 2 independent records of the Eurasian Lynx in a bare rocky habitat, which is known to be widely occupied by this species in central Asia (Breitenmoser et al. 2015).

The Siberian Ibex was abundant throughout the research area, and it can be easily seen anytime nearby any rocky area. The naïve occupancy of this species outside of the Small Gobi-A SPA is 0.8 (Table 3), which means that 8/10 sites were occupied by Siberian Ibex among those sites sampled by camera traps.

The species captured by cameras that are also frequently sighted were the Red Fox and the Tolai Hare (*Lepus tolai* Pallas, 1778). The 2 species, along with the Siberian Ibex, have been recorded in the highest number of sites if considering the total area including the protected area and its BA (Table 3).

Sample-size-based rarefaction sampling curves (Fig. 2) show that the highest species richness was found in

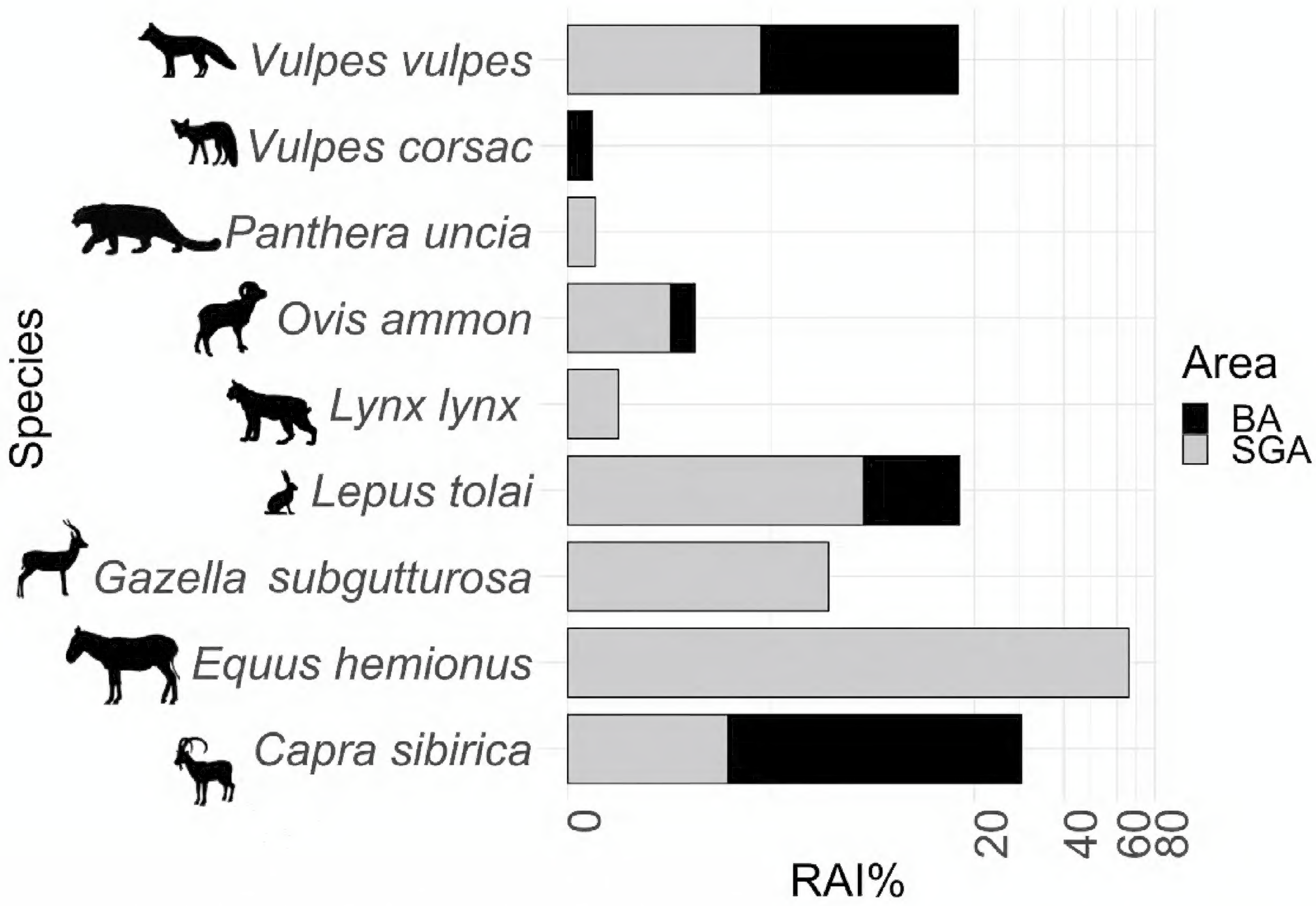


**Figure 3.** Relative abundance index each species detected by camera trap in the Small Gobi-A (SGA) and in the boundary area (BA). RAI values are log10 plus one transformed.

the Small Gobi-A SPA.

Eight species of mammals were recorded by occasional sightings: *Capra sibirica*, *Equus hemionus*, *Gazella subgutturosa*, *Ovis ammon*, *Procapra gutturosa* (Pallas, 1777), *Spermophilus pallidicauda* (Satunin, 1903), *Vulpes corsac*, and *Vulpes vulpes* (Table 4).

Seven small mammal species (<1 kg) were captured with live trapping (Table 4), including species belonging the orders Rodentia and Eulipotyphla.

Tissue samples and body measurements were collected for 23 individuals of 42 captures. The most commonly captured species were Gerbils (*Meriones meridianus* (Pallas, 1773) and *M. unguiculatus* (Milne-Edwards, 1867)), Phodopus hamsters (*Cricetulus migratorius* (Pallas, 1773) and *Phodopus roborovskii* (Satunin, 1903)), less frequently Long-eared Hedgehog (*Hemiechinus auratus* (Gmelin, 1770)), Jerboas (*Dipus sagitta* (Pallas, 1773), and *Allactaga bullata* (Allen, 1925)) (Table 4).

## Annotated list

### *Allactaga bullata* Allen, 1925

**Records.** One individual was recorded in May 13, 2017 in the live trapping site LSH16 (43°11.039′ N, 105°45.276′ E – time 9:40 pm); Figure 5K.

**Table 3.** List of species detected by camera traps in the Small Gobi-A Strictly Protected Area (SGA) and its boundary area (BA). Events = Independent events (captures with a minimum time distance of 30 minutes); RAI = Relative abundance index; No. of occupied sites = total number of sites where the species was detected by cameras; Naïve occupancy = proportion of sites at which the species was detected.

| Scientific name | Events | RAI | No. of occupied sites | Naïve occupancy | Area |
|---|---|---|---|---|---|
| *Equus hemionus* | 282 | 38.525 | 3 | 0.143 | SGA |
| *Lepus tolai* | 35 | 4.781 | 10 | 0.476 | SGA |
| *Gazella subgutturosa* | 26 | 3.552 | 1 | 0.048 | SGA |
| *Capra sibirica* | 10 | 1.366 | 6 | 0.286 | SGA |
| *Vulpes vulpes* | 14 | 1.913 | 8 | 0.381 | SGA |
| *Ovis ammon* | 5 | 0.683 | 3 | 0.143 | SGA |
| *Lynx lynx* | 2 | 0.273 | 2 | 0.095 | SGA |
| *Panthera uncia* | 1 | 0.137 | 1 | 0.048 | SGA |
| *Capra sibirica* | 38 | 4.691 | 8 | 0.800 | BA |
| *Vulpes vulpes* | 16 | 1.975 | 5 | 0.500 | BA |
| *Lepus tolai* | 5 | 0.617 | 2 | 0.200 | BA |
| *Ovis ammon* | 1 | 0.123 | 1 | 0.100 | BA |
| *Vulpes corsac* | 1 | 0.123 | 1 | 0.100 | BA |

**Table 4.** Coordinates of the species records. ID = Site code; CUIM = coordinate uncertainty in meters, horizontal distance (in meters) from the given decimal latitude and decimal longitude describing the smallest circle containing the whole of the location; Methods = Methods with which the different species have been recorded throughout the study by occasional sightings (OS), camera trapping (CT), or live trapping (LT); Area = ID of the Small Gobi-A (SGA) and its boundary area (BA). Geographic coordinates use the WGS84 datum.

| Scientific name | ID | Latitude (N) | Longitude (E) | Recorded by | Verbatim elevation (m) | Method | CUIM | Area |
|---|---|---|---|---|---|---|---|---|
| *Allactaga bullata* | LSH16 | 43°11.039′ | 105°45.276′ | C. Augugliaro | 1503 | LT | ± 200 | BA |
| *Capra sibirica* | SGHI2 | 43°25.311′ | 106°11.725′ | C. Augugliaro | 1522 | CT | ± 5 | BA |
| *Capra sibirica* | SGBH1 | 42°51.758′ | 105°49.782′ | C. Augugliaro | 1486 | CT | ± 5 | BA |
| *Capra sibirica* | SGCI4 | 42°57.241′ | 105°37.608′ | C. Augugliaro | 1716 | CT | ± 5 | BA |
| *Capra sibirica* | SGCI1 | 42°54.405′ | 105°41.195′ | C. Augugliaro | 1649 | CT | ± 5 | BA |
| *Capra sibirica* | SGCI2 | 42°55.676′ | 105°39.955′ | C. Augugliaro | 1700 | CT | ± 5 | BA |
| *Capra sibirica* | SGCI3 | 42°57.475′ | 105°37.725′ | C. Augugliaro | 1791 | CT | ± 5 | BA |
| *Capra sibirica* | SGHA3 | 43°11.846′ | 105°20.244′ | C. Augugliaro | 1809 | CT | ± 5 | BA |
| *Capra sibirica* | SGAPA14 | 42°27.634′ | 105°41.990′ | C. Augugliaro | 1356 | CT | ± 5 | SGA |
| *Capra sibirica* | SGAPA17 | 42°10.112′ | 106°02.646′ | C. Augugliaro | 1358 | CT | ± 5 | SGA |
| *Capra sibirica* | OS2 | 42°57.922′ | 105°40.691′ | C. Augugliaro |  | OS | ± 1000 | BA |
| *Cricetulus migratorius* | SHC5 | 43°11.092′ | 105°45.329′ | I. E. Monti | 1502 | LT | ± 200 | BA |
| *Dipus sagitta* | LSH16 | 43°11.039′ | 105°45.276′ | C. Augugliaro | 1503 | LT | ± 200 | BA |
| *Equus hemionus* | SGAPA03 | 42°16.950′ | 106°04.359′ | C. Augugliaro |  | CT | ± 5 | SGA |
| *Equus hemionus* | OSSGAPA03 | 42°16.950′ | 106°04.359′ | C. Augugliaro |  | OS | ± 5 | SGA |
| *Equus hemionus* | SGAPA06 | 42°20.318′ | 105°55.075′ | C. Augugliaro | 1121 | CT | ± 5 | SGA |
| *Equus hemionus* | OS4 | 42°40.256′ | 106°14.922′ | C. Augugliaro |  | OS | ± 1000 | SGA |
| *Gazella subgutturosa* | SGAPA03 | 42°16.950′ | 106°04.359′ | C. Augugliaro |  | CT | ± 5 | SGA |
| *Gazella subgutturosa* | OS3 | 43°02.556′ | 106°17.539′ | C. Augugliaro |  | OS | ± 1000 | BA |
| *Gazella subgutturosa* | OS5 | 42°52.091′ | 106°09.608′ | C. Augugliaro |  | OS | ± 1000 | SGA |
| *Gazella subgutturosa* | OS6 | 42° 32.915′ | 106° 40.173′ | C. Augugliaro |  | OS | ± 1000 | SGA |
| *Gazella subgutturosa* | OS1 | 43°16.030′ | 106°39.954′ | C. Augugliaro |  | OS | ± 1000 | BA |
| *Hemiechinus auritus* | LSH16 | 43°11.039′ | 105°45.276′ | I. E. Monti | 1503 | LT | ± 200 | BA |
| *Lepus tolai* | SGCI5 | 42°58.545′ | 105°35.973′ | C. Augugliaro | 1776 | CT | ± 5 | BA |
| *Lepus tolai* | SGHA3 | 43°11.846′ | 105°20.244′ | C. Augugliaro | 1809 | CT | ± 5 | BA |
| *Lepus tolai* | SGAPA06 | 42°20.318′ | 105°55.075′ | C. Augugliaro | 1121 | CT | ± 5 | SGA |
| *Lepus tolai* | SGAPA11 | 42°23.281′ | 105°48.030′ | C. Augugliaro | 1193 | CT | ± 5 | SGA |
| *Lepus tolai* | SGAPA13 | 42°27.468′ | 105°43.063′ | C. Augugliaro | 1306 | CT | ± 5 | SGA |
| *Lepus tolai* | SGAPA18 | 42°25.230′ | 105°43.990′ | C. Augugliaro | 1427 | CT | ± 5 | SGA |
| *Lepus tolai* | OS2 | 42°57.922′ | 105°40.691′ | C. Augugliaro |  | OS | ± 1000 | BA |
| *Lynx lynx* | SGAPA03 | 42°16.950′ | 106°04.359′ | C. Augugliaro |  | CT | ± 5 | SGA |
| *Lynx lynx* | SGAPA8 | 43°11.015′ | 105°45.257′ | C. Augugliaro | 1102 | CT | ± 5 | SGA |
| *Meriones meridianus* | LSH6 | 43°11.812′ | 105°38.781′ | I. E. Monti | 1553 | LT | ± 200 | BA |
| *Meriones meridianus* | SHC5 | 43°11.092′ | 105°45.329′ | I. E. Monti | 1505 | LT | ± 200 | BA |
| *Meriones meridianus* | LSH16 | 43°11.039′ | 105°45.276′ | I. E. Monti | 1503 | LT | ± 200 | BA |
| *Meriones unguiculatus* | LSH16 | 43°11.039′ | 105°45.276′ | I. E. Monti | 1503 | LT | ± 200 | BA |
| *Ovis ammon* | SGHI2 | 43°25.311′ | 106°11.725′ | C. Augugliaro | 1522 | CT | ± 5 | BA |
| *Ovis ammon* | SGAPA03 | 42°16.950′ | 106°04.359′ | C. Augugliaro |  | CT | ± 5 | SGA |
| *Ovis ammon* | SGAPA06 | 42°20.318′ | 105°55.075′ | C. Augugliaro | 1121 | CT | ± 5 | SGA |
| *Ovis ammon* | SGAPA11 | 42°23.281′ | 105°48.030′ | C. Augugliaro | 1193 | CT | ± 5 | SGA |
| *Ovis ammon* | SGAPA14 | 42°27.634′ | 105°41.990′ | C. Augugliaro | 1356 | CT | ± 5 | SGA |
| *Ovis ammon* | OS1 | 43°16.030′ | 106°39.954′ | C. Augugliaro |  | OS | ± 1000 | BA |
| *Ovis ammon* | OS2 | 42°57.922′ | 105°40.691′ | C. Augugliaro |  | OS | ± 1000 | BA |
| *Panthera uncia* | SGAPA14 | 42°27.634′ | 105°41.990′ | C. Augugliaro | 1356 | CT | ± 5 | SGA |
| *Phodopus roborovskii* | LSH6 | 43°11.812′ | 105°38.781′ | I. E. Monti | 1553 | LT | ± 200 | BA |
| *Phodopus roborovskii* | SHC5 | 43°11.092′ | 105°45.329′ | I. E. Monti | 1502 | LT | ± 200 | BA |
| *Procapra gutturosa* | OS3 | 43°02.556′ | 106°17.539′ | C. Augugliaro |  | OS | ± 1000 | BA |
| *Spermophilus pallidicauda* | OS1 | 43°16.030′ | 106°39.954′ | C. Augugliaro |  | OS | ± 1000 | BA |
| *Vulpes corsac* | SGHI1 | 43°21.124′ | 106°12.802′ | C. Augugliaro | 1460 | CT | ± 5 | BA |
| *Vulpes corsac* | OS3 | 43°02.556′ | 106°17.539′ | C. Augugliaro |  | OS | ± 1000 | BA |
| *Vulpes vulpes* | SGCI4 | 42°57.241′ | 105°37.608′ | C. Augugliaro | 1716 | CT | ± 5 | BA |
| *Vulpes vulpes* | SGCI2 | 42°55.676′ | 105°39.955 | C. Augugliaro | 1700 | CT | ± 5 | BA |
| *Vulpes vulpes* | SGCI5 | 42°58.545′ | 105°35.973′ | C. Augugliaro | 1776 | CT | ± 5 | BA |
| *Vulpes vulpes* | SGHI2 | 43°25.311′ | 106°11.725′ | C. Augugliaro | 1522 | CT | ± 5 | BA |
| *Vulpes vulpes* | SGAPA03 | 42°16.950′ | 106°04.359′ | C. Augugliaro |  | CT | ± 5 | SGA |
| *Vulpes vulpes* | SGAPA06 | 42°20.318′ | 105°55.075′ | C. Augugliaro | 1121 | CT | ± 5 | SGA |
| *Vulpes vulpes* | SGAPA13 | 42°27.468′ | 105°43.063′ | C. Augugliaro | 1306 | CT | ± 5 | SGA |
| *Vulpes vulpes* | SGAPA21 | 42°08.681′ | 106°02.554′ | C. Augugliaro | 989 | CT | ± 5 | SGA |
| *Vulpes vulpes* | SGAPA23 | 42°14.468′ | 106°04.257′ | C. Augugliaro | 1082 | CT | ± 5 | SGA |
| *Vulpes vulpes* | SGAPA5 | 42°22.308′ | 105°50.450′ | C. Augugliaro | 1171 | CT | ± 5 | SGA |
| *Vulpes vulpes* | SGAPA9 | 42°22.731′ | 105°47.122′ | C. Augugliaro | 1421 | CT | ± 5 | SGA |
| *Vulpes vulpes* | OS2 | 42°57.922′ | 105°40.691′ | C. Augugliaro |  | OS | ± 1000 | BA |

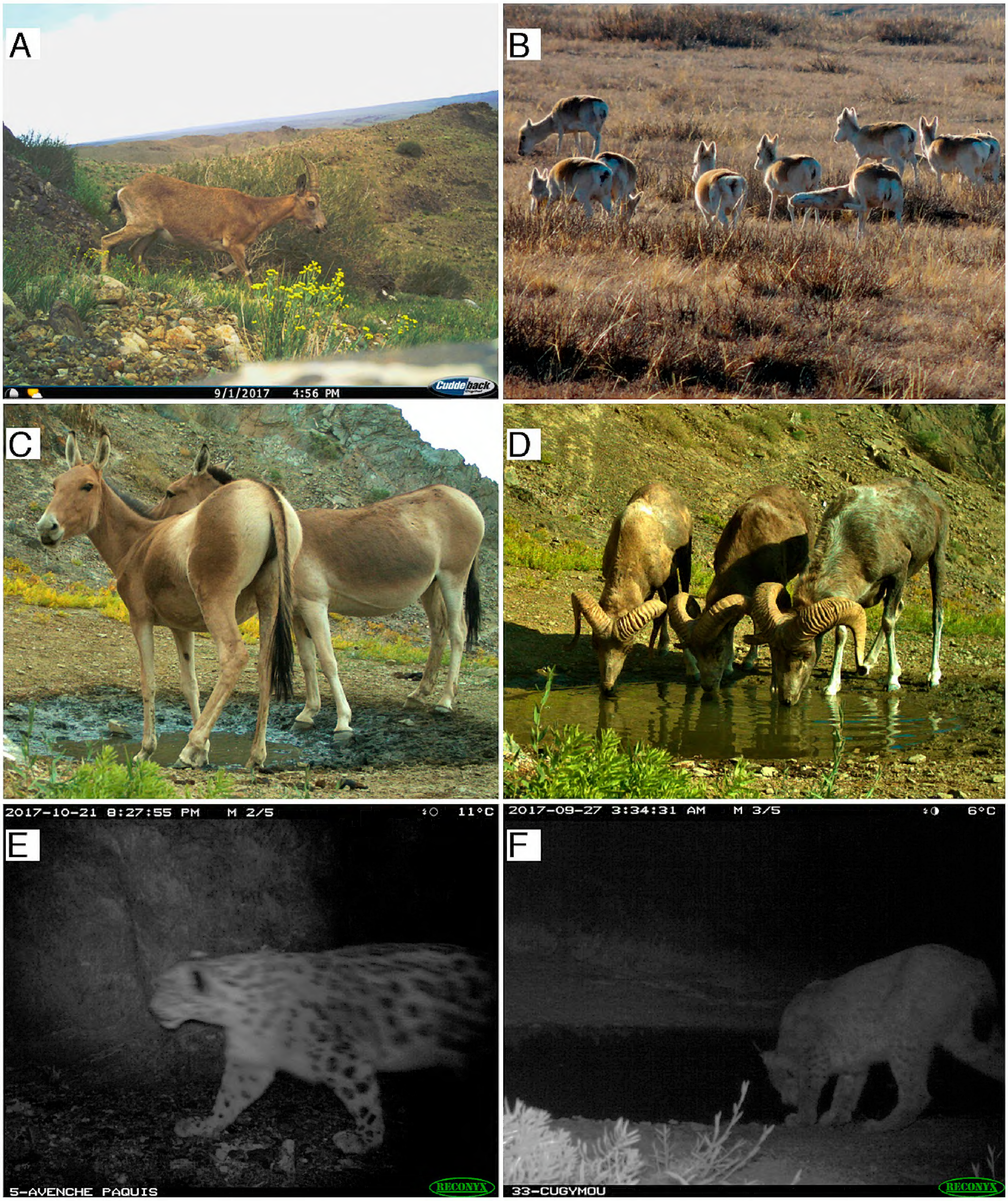


**Figure 4.** Photographs of large mammal species photographed by camera traps or occasionally during the fieldwork. **A.** *Capra sibirica*. **B.** *Procapra gutturosa*. **C.** *Equus hemionus*. **D.** *Ovis ammon*. **E.** *Panthera uncia*. **F.** *Lynx lynx*.

**Identification.** We based the identification on morphometric and qualitative characters. A white stripe on the tail differentiates this species from other jerboas as well the morphology of hind limbs and the length of the ears (Smith et al. 2010, Batsaikhan 2014).

***Capra sibirica*** **Pallas, 1776**

**Records.** First record was made by camera trapping in May 18, 2017 (43°25.311′N, 106°11.725′E – camera trap SGHI2 – time 9:20 pm), and subsequently in the monitoring sites SGBH1, SGCI1, SGCI2, SGCI3, SGCI4, SGHA3, SGAPA14, SGAPA17, OS2 (Table 4); Figure 4A.

**Identification.** It is the only wild goat occurring in the area and there are not similar species in the area (Batsaikhan 2014).

***Cricetulus migratorius*** **(Pallas, 1773)**

**Records.** Individuals were captured in the monitoring

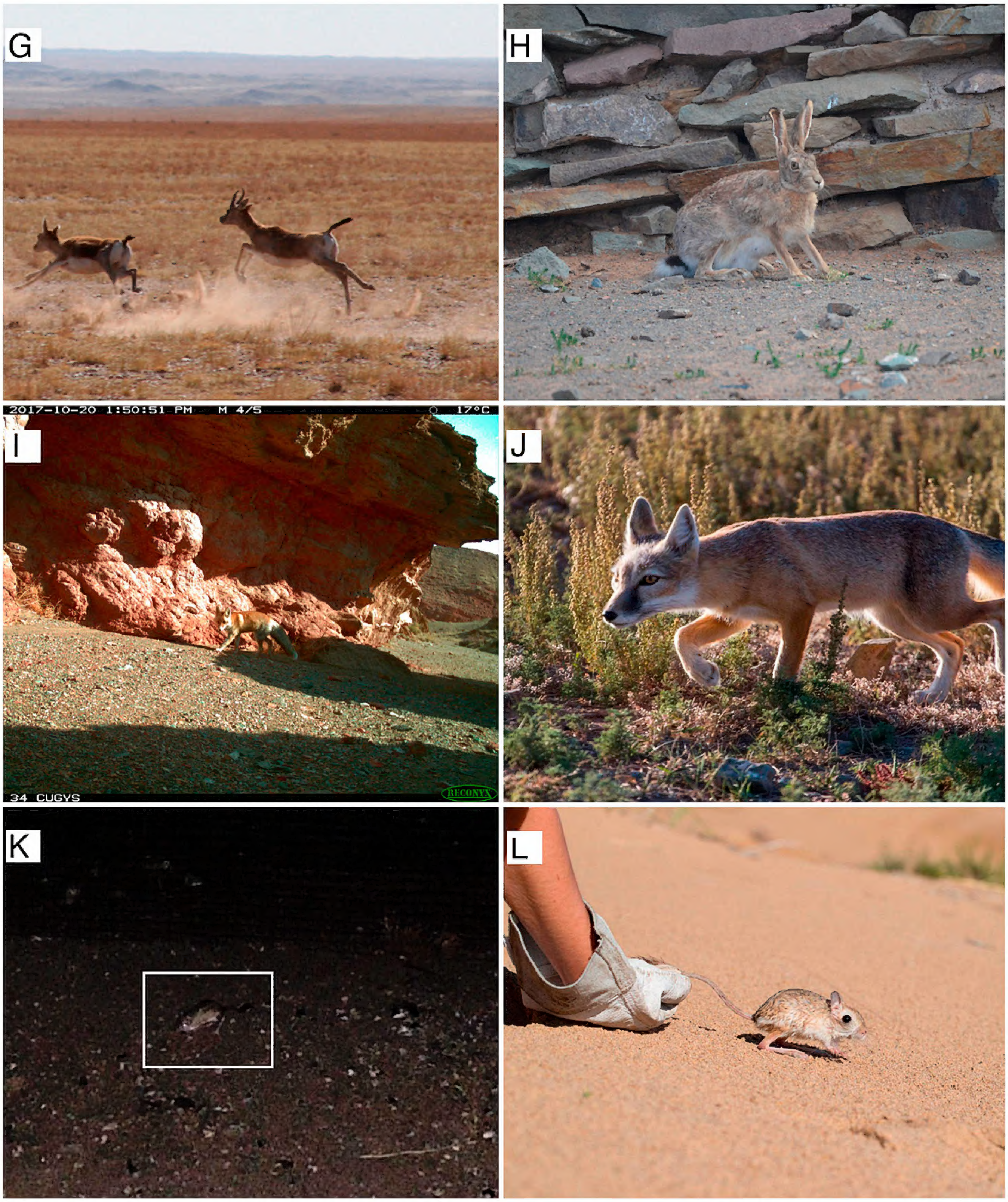


**Figure 5.** Photographs of mammal species photographed by camera traps, during the live trapping surveys or occasionally during the fieldwork. **G.** *Gazella subgutturosa*. **H.** *Lepus tolai*. **I.** *Vulpes corsac*. **J.** *Vulpes vulpes*. **K.** *Allactaga bullata*. **L.** *Dipus sagitta*.

site SHC5 (43°11.092′N, 105°45.329′E – time 07:30 pm), for the first time the presence was recorded in August 11, 2017; Figure 6R.

**Identification.** We based the identification on morphometric and qualitative characters. This species differs from other hamsters in having the ears and their margin homogeneously colored as well as the lower and upper part of the tail (Batsaikhan 2014). Forefoot have 5 palmar tubercles, while hindfoot have 6 plantar tubercles (Pardiñas et al. 2017).

***Dipus sagitta* (Pallas, 1773)**

**Records.** One individual was recorded in August 08, 2017 in the monitoring site LSH16 (43°11.039′N, 105°45.276′E – 10:10 am); Figure 5L.

**Identification.** We based the identification on morphometric and qualitative characters. This species has a longer tail compared to other jerboa species occurring in

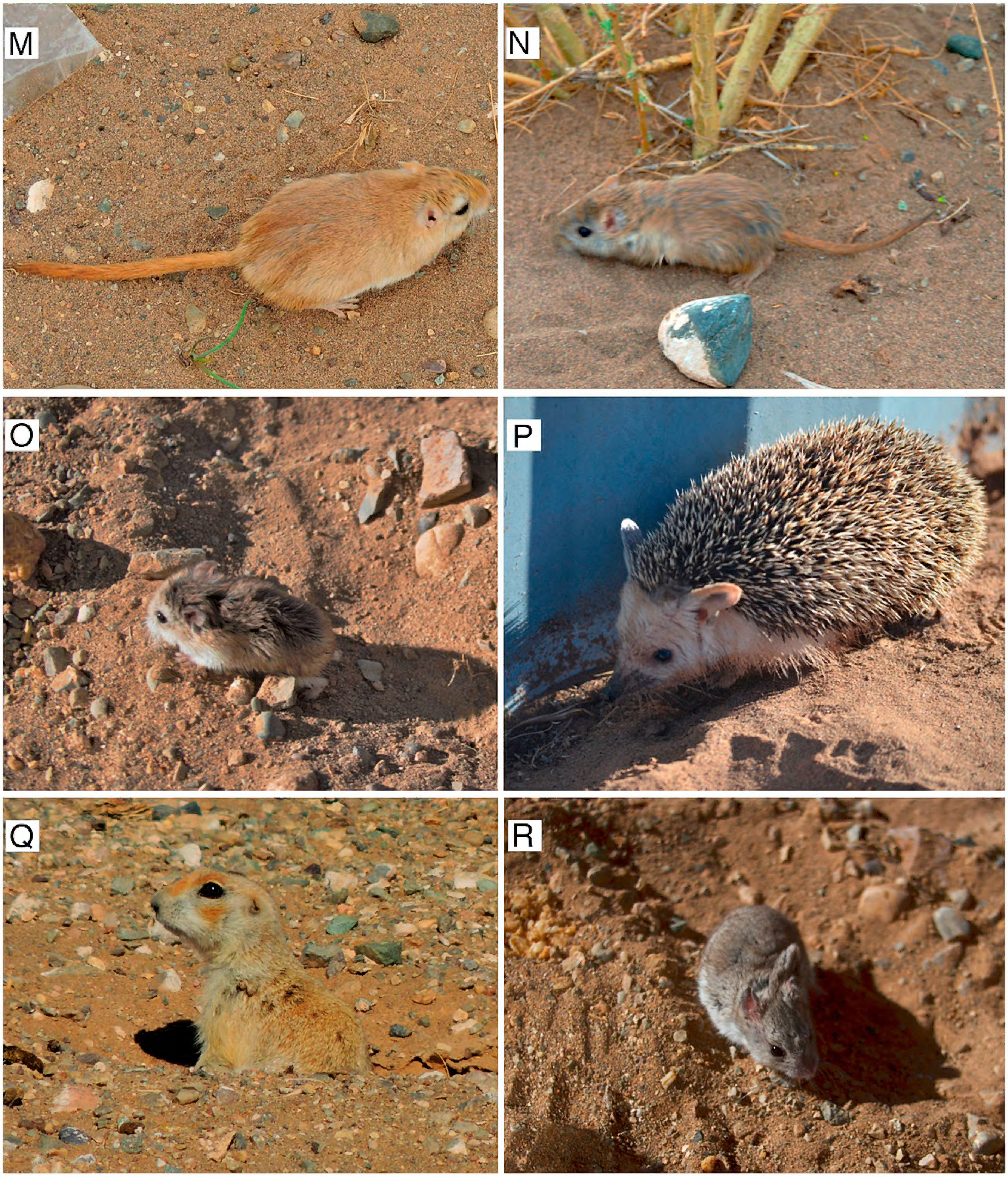


**Figure 6.** Photographs of small mammal species photographed during the live trapping surveys or occasionally during the fieldwork. **M.** *Meriones unguiculatus*. **N.** *Meriones meridianus*. **O.** *Phodophus roborovskii*. **P.** *Hemiechinus auritus*. **Q.** *Spermophilus pallidicauda*. **R.** *Cricetulus migratorius*.

the area. The tail has a well developed black and white flag. The ears are considerably shorter than any similar species. The hind feet have 3 toes (Smith et al. 2010, Batsaikhan 2014).

### *Equus hemionus* Pallas, 1775

**Records.** First record was made in September 14, 2017 (42°16.950′N, 106°04.359′E – occasional sighting OSSGAPA03 – 3:50 pm) before than the installation of the camera trap SGAPA03, and subsequently in the monitoring sites (camera trap SGAPA03, SGAPA06 and occasional sighting site OS4; see Table 4 for the coordinates). Figure 4C refers to camera trap site SGAPA03.

**Identification.** No similar species live in the area (Clark et al. 2006).

### *Gazella subgutturosa* (Güldenstädt, 1780)

**Records.** First record was in May 08, 2017 (43°02.556′N,

106°17.539′ E – occasional sighting OS3 – 11:07 am), and subsequently in the occasional sighting monitoring sites OS1, OS5, OS6 and camera trap SGAPA03 (Table 4); Figure 5G.

**Identification.** The coat color is well demarcated between the reddish back and the white belly, and the tail is black (Groves and Grubb 2011).

### *Hemiechinus auritus* (Gmelin, 1770)

**Material examined.** First individual was recorded in August 11, 2017 in the monitoring site LSH16 (43° 11.039′ N, 105°45.276′ E – time 07:00 am); Figure 6P.

**Identification.** It is 1 of 2 species belonging to Erinaceidae which occurr in Mongolia, but their distributions in the country do not overlap. *Hemiechinus auritus* is easily recognizable by its relatively longer ears and snout (Batsaikhan 2014).

### *Lepus tolai* Pallas, 1778

**Records.** First record was in August 1, 2017 (42°57.922′ N, 105°40.691′ E – occasional sighting OS2 – time: 2:39 pm), and subsequently in the monitoring site SGHA3, SGCI5, SGAPA06, SGAPA11, SGAPA13, SGAPA18 (Table 4); Figure 5H.

**Identification.** This is the only species of Leporidae occurring in the study area (Batsaikhan 2014, Schai-Braun and Hackländer 2016).

### *Lynx lynx* (Linnaeus, 1758)

**Records.** First record was captured by camera trapping in September 27, 2017 (42°16.950N, 106°04.359′ E – camera trap SGAPA03 – 3:34 am), and subsequently in October 30, 2017 (43°11.015′ N, 105° 45.257′ E – camera trap SGAPA8 – 4.33 am); Figure 4F.

**Identification.** There are no similar species in the area (Batsaikhan 2014).

### *Meriones meridianus* (Pallas, 1773)

**Records.** First specimen was captured by live trapping in May 14, 2017 (43°11.039′ N, 105°45.276′ E – site LSH16 – time 8:00 am), and subsequently in SHC5, LSH6 (Table 4); Figure 6N.

**Identification.** We based the identification on morphometric and qualitative characters. The tail is relatively longer than the head and body. It differs from *Meriones unguiculatus* in having a less-developed tuft of the tail; the tuft is sometimes absent. The dorsal part of the tail is yellowish brown and its ventral part is light yellow. The sole of the hind feet is covered with hairs. The claws are white with a reddish upper part. The underbelly is white (Darvish 2009, Smith et al. 2010).

### *Meriones unguiculatus* (Milne-Edwards, 1867)

**Records.** The only record was made by live trapping in May 14, 2017 (43°11.039′ N, 105°45.276E ‘– site LSH16 – time 8:30 am); Figure 6M.

**Identification.** The individual was identified based on morphometric and qualitative characters. It could be mistaken for the *Meriones meridianus*, which also occurs in the area (Batsaikhan 2014). It may be distinguished by the *Meriones meridianus* by the black claws and the differently colored tail, which has a dark-black tip. The ratio of body to tail length in *Meriones unguiculatus* is smaller than *Meriones meridianus* (Darvish 2009, Smith et al. 2010).

### *Ovis ammon* Linnaeus, 1758

**Records.** First record was in August 14, 2017 (43°25.311′ N, 106°11.725′ E – camera trap SGHI2 – 5:04 pm), and subsequently in the monitoring sites (SGAPA03, SGAPA06, SGAPA11, SGAPA14, OS2, OS1; see Table 4 for the coordinates); Figure 4D.

**Identification.** It is the only wild sheep species in the area and there are no similar species (Batsaikhan 2014).

### *Phodopus roborovskii* (Satunin, 1903)

**Records.** First record was in August 12, 2017 in the live trapping site SHC5 (43°11.092′ N, 105°45.329′ E – 09:00 am), and subsequently in the monitoring site LSH6 (Table 4); Figure 6O.

**Identification.** We based the identification on morphometric and qualitative characters. It is smaller than Campbell's Hamster (*Phodopus campbelli* (Thomas, 1905)) and does not have the stripe on the back. The feet are covered with white hairs. It has a relatively long and sharp snout (Batsaikhan 2014).

### *Procapra gutturosa* (Pallas, 1777)

**Records.** Individuals were recorded in May 08, 2017 in the occasional sighting site OS3 (43°02.556′ N, 106°17.539′ E – 11:07 am); Figure 4B.

**Identification.** The coat is lighter than *Gazella subgutturosa* and has a light gradient from back to belly. The tail is shorter and lighter compared to *G. subgutturosa* (Batsaikhan 2014).

### *Panthera uncia* (Schreber, 1775)

**Records.** The only record was referred to camera trap site SGAPA14 (42°27.634′ N, 105°41.990′ E in October 21, 2017 – 8:27 pm); Figure 4E.

**Identification.** The species cannot be misidentified with other felids occurring in the study area.

### *Spermophilus pallidicauda* (Satunin, 1903)

**Records.** One Individual was recorded in May, 11 2017 in the monitoring site OS1 – 43°16.030′ N, 106° 39.954’ E – 4:30 pm; Figure 6Q.

**Identification.** Based on morphometric and qualitative characters. It can be distinguished by the Alashan Ground Squirrel (*Spermophilus alashanicus* (Büchner, 1888)) by its considerably shorter tail (tail <55 mm; Smith et al. 2010). It has reddish spots beneath the eyes (Smith et al. 2010, Batsaikhan 2014).

***Vulpes corsac* (Linnaeus, 1768)**

**Records.** First record was in August 12, 2017 in the occasional sightings site OS3 (43°02.556′N, 106°17.539′E – 7:00 pm); and subsequently in the monitoring site SGHI1 (Table 4); Figure 5J.

**Identification.** It is 1 of the 2 species belong to genus *Vulpes* (the other being *Vulpes vulpes*) occurring in Mongolia. It is smaller than *V. vulpes* and can be distinguished by the shorter black-tipped tail and yellowish-white legs (Batsaikhan 2014).

***Vulpes vulpes* (Linnaeus, 1758)**

**Records.** First record was in May 19, 2017 (42°57.241′N, 105°37.608′E – camera trap SGCI4 – time 1:52 am), and subsequently in the monitoring sites (SGHI2, SGCI2, SGCI5, SGAPA03, SGAPA06, SGAPA13, SGAPA21, SGAPA23, SGAPA5, SGAPA9, OS2; for details see Table 4); Figure 5I.

**Identification.** It can be distinguished by *Vulpes corsac* by its long, bushy, white-tipped tail, black-backed ears, and longer, darker legs (Batsaikhan 2014).

# Discussion

We recorded 18 mammal species out of 31 non-volant mammal species potentially occurring in the study area (Batsaikhan 2014). Our results clearly show that the Small Gobi-A protected area serves as an important reservoir of biodiversity in the South Gobi province.

The presence of the Snow Leopard is well known in the western side of the Mongolian Alashan Plateau semi-desert Ecoregion and occurs in the Great Gobi SPA, on Tost Mountain, in the Gobi Gurvansaikhan SPA, and also in the western side of the Small Gobi-A SPA (Nyhus et al. 2016). Our record of this species is the first that has been documented in the study area and the southeasternmost record in Mongolia according to the literature (McCarthy 2000). The conservation of such a charismatic species could represent an important opportunity to protect other sympatric carnivores and persecuted wildlife species (Alexander et al. 2016).

Very little is known about the Eurasian Lynx in Mongolia and generally the data are collected within projects aimed to study the carnivore communities such as in Khustai National Park or in Ikh Nart Nature Reserve (Murdoch et al. 2006). However, apart from a few occurrence data, no literature is available for studies conducted in Mongolia on the Eurasian Lynx. The 2 records of the species with a limited sampling effort is very encouraging.

The study area represents an important refuge for the wild ungulates: the Argali is a globally Near Threatened species (Table 1), and its distribution in Mongolia is very scattered (Lkhagvasuren et al. 2016). The abundance of this species in the study area seems to be fairly high, even if it has not been estimated, as the species could be spotted quite easily close to the rock outcrops. The globally threatened Goitered Gazelle (Table 1), lives abundantly throughout the area. We spotted many herds of gazelles both inside and outside of the protected area, and the largest herd, in August was over a thousand of individuals. The results show the presence in the study area of a diverse community of non-volant mammals with several species of conservation relevance, besides Snow Leopard. The multiple methodologies used to conduct this research gave sufficient data to build a satisfactory mammal checklist. Among the methodologies used, camera trapping is the most reliable method to gather information about medium-sized to large mammals, as it enables to detect the most elusive species (Rowcliffe and Carbone 2008, Rovero and Zimmermann 2016). Moreover, every record is supported by a photograph, reducing the chance of misidentifications, and the sampling was carried out over an extended time period. However, the accumulation curves (Fig. 2) demonstrate that a higher sampling effort is needed to satisfactorily sample the mammals in the area. The use of more cameras for a shorter time period is preferable than fewer cameras for a longer period (Si et al. 2014).

Moreover, live trapping presents some limitations. It is difficult to sample areas which are too far from the base camp because it is necessary to check the traps once or twice per day. Anyhow, we covered all the different desert habitats in our study area, and this methodology gave a considerable contribution to our checklist.

Because of to the limited sampling time and logistic constraints to conduct a live trapping survey in a wider area, the number of small mammal species recorded was limited (Tables 1, 4). Also, we highlight the absence of 2 carnivores potentially present in the study area: Gray Wolf (*Canis lupus* Linnaeus, 1758) and Marbled Polecat (*Vormela peregusna* (Güldenstädt, 1770)) (Batsaikhan et al., 2014). The lack of records for these species might be due to a false absence (i.e. they are present but were not detected). Probably, the absence of records can be interpreted as a sign of a very low density in the study area of these species.

Despite the fact that the boundary area has been exploited for mineral extraction, the mammal community in the area can be considered relatively well preserved. The record of a flagship species, such as the Snow Leopard, close to the protected area border, may encourage the local authorities to enlarge the Small Gobi-A SPA perimeter. The expansion of the protected area to the north would encompass a mountainous area hosting a high number of Siberian Ibex, which would provide support for the dispersal of the Snow Leopard across the border of the protected area.

The Snow Leopard is a highly mobile species and our research shows that it is present across the south-easternmost continuous mountains and flatlands. Therefore, given the high capacity of dispersion of the species across mountain ranges and deserts, we recommend to include actions of cross-border conservation strategies between Mongolia and China.

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## Authors' Contributions

CA, CJ, and BM conceived the research. CA and IEM collected the data in the field. CA and CP analyzed the data and produced the figures. CA and CP wrote and revised the manuscript. All authors collected data or identified the specimens, discussed the results, and contributed to the final manuscript.

## References

Alexander JS, Cusack JJ, Pengju C, Kun S, Riordan P (2016) Conservation of Snow Leopards: spill-over benefits for other carnivores? Oryx 50: 239–243. https://doi.org/10.1017/S0030605315001040

Badyaev AV, Foresman KR (2000) Extreme environmental change and evolution: stress-induced morphological variation is strongly concordant with patterns of evolutionary divergence in shrew mandibles. Proceedings of the Royal Society of London B: Biological Sciences 267: 371–377. https://doi.org/10.1098/rspb. 2000.1011

Batsaikhan N (2014) A Field Guide to the Mammals of Mongolia. Zoological Society of London, London, 323 pp.

Bolger DT, Vance B, Morrison TA, Farid H (2011) WildID User Guide: Pattern Extraction and Matching Software for Computer-Assisted Photographic Mark-Recapture Analysis. Dartmouth College, Hanover, NH: 1–12.

Breitenmoser U, Breitenmoser-Würsten C, Lanz T, Arx M von, Antonevich A, Bao W, Avgan B (2015) *Lynx lynx* (errata version published in 2017). The IUCN Red List of Threatened Species 2015: e.T12519A121707666. https://www.iucnredlist.org/species/12519/121707666. Accessed on: 2018-07-13.

Burton AC, Neilson E, Moreira D, Ladle A, Steenweg R, Fisher JT, Bayne E, Boutin S (2015) Wildlife camera trapping: a review and recommendations for linking surveys to ecological processes. Journal of Applied Ecology 52: 675–685. https://doi.org/10.1111/1365-2664.12432

Clark EL, Munkhbat J, Dulamtseren S, Baillie JEM, Batsaikhan N, Samiya R, Stubbe M (2006) Mongolian Red List of Mammals. Summary Conservation Action Plans for Mongolian Mammals. 2 vol. Zoological Society of London, London, 26–28 pp.

Darvish J (2011) Morphological comparison of fourteen species of the genus *Meriones* Illiger, 1811 (Rodentia: Gerbillinae) from Asia and North Africa. Iranian Journal of Animal Biosystematics 5: 59–77.

Dilts TE (2015) Topography Tools for ArcGIS 10.1. University of Nevada Reno. http://www.arcgis.com/home/item.html?id=b13b3b40fa3c43d4a23a1a09c5fe96b9. Accessed on: 2018-01-01.

Durant S, Pettorelli N, Bashir S (2012) Forgotten biodiversity in desert ecosystems. Science 336: 1379–1380. https://doi.org/10.1126/science.336.6087.1379

Flowerdew JR, Shore RF, Poulton SMC, Sparks TH (2004) Live trapping to monitor small mammals in Britain. Mammal Review 34: 31–50. https://doi.org/10.1046/j.0305-1838.2003.00025.x

Groves C, Grubb P (2011) Ungulate Taxonomy. Johns Hopkins University Press, Baltimore, Maryland, 331 pp.

Hsieh TC, Ma KH, Chao A (2016) iNEXT: an R package for interpolation and extrapolation of species diversity (Hill numbers). Methods in Ecology and Evolution 7: 1451–1456. https://doi.org/10.1111/2041-210X.12613

IUCN (2018) The IUCN Red List of Threatened Species. International Union for Conservation of Nature and Natural Resources, Gland, Switzerland. Version 2018.1. https://www.iucn.org. Accessed on: 2018-8-25.

John R, Chen J, Lu N, Wilske B (2009) Land cover/land use change in semi-arid Inner Mongolia: 1992–2004. Environmental Research Letters 4: 045010. https://doi.org/10.1088/1748-9326/4/4/045010

Kaczensky P, Adiya Y, von Wehrden H, Mijiddorj B, Walzer C, Güthlin D, Enkhbileg D, Reading RP (2014) Space and habitat use by wild Bactrian camels in the Transaltai Gobi of southern Mongolia. Biological Conservation 169: 311–318. https://doi.org/10.1016/j.biocon.2013.11.033

Lamchin M, Lee J-Y, Lee W-K, Lee EJ, Kim M, Lim C-H, Choi H-A, Kim S-R (2016) Assessment of land cover change and desertification using remote sensing technology in a local region of Mongolia. Advances in Space Research 57: 64–77. https://doi.org/10.1016/j.asr.2015.10.006

Lebedev VS, Bannikova AA, Adiya Ya, Shar S, Surov AV (2016) A revised checklist of Mongolian mammal species. Erforschung Biologischer Ressourcen der Mongolei 13: 349–360.

Lkhagvasuren B, Adiya Y, Tsogtjargal G, Amgalanbaatar G, Harris R (2016) Current status and conservation of mountain ungulates in Mongolia. Erforschung Biologischer Ressourcen der Mongolei 13: 445–456.

Lomolino M V, Riddle BR, Whittaker RJ, Brown JH (2010) Biogeography. Sinauer, Sunderland, MA, 560 pp.

MacKenzie DI, Nichols JD (2004) Occupancy as a surrogate for abundance estimation. Animal Biodiversity and Conservation 27: 461–467.

MacKenzie DI, Nichols JD, Lachman GB, Droege S, Royle AA, Langtimm CA (2002) Estimating site occupancy rates when detection probabilities are less than one. Ecology 83: 2248–2255. https://doi.org/10.1890/0012-9658(2002)083[2248:esorwd]2.0.co;2

McCarthy TM (2000) Ecology and conservation of Snow Leopards, Gobi Brown Bears, and wild Bactrian Camels in Mongolia. PhD dissertation, University of Massachusetts, Amherst, USA, 134 pp.

McCarthy TM, Fuller TK, Munkhtsog B (2005) Movements and activities of Snow Leopards in southwestern Mongolia. Biological Conservation 124: 527–537. https://doi.org/10.1016/j.biocon.2005.03.003

Murdoch JD, Munkhzul T, Amgalanbaatar S, Reading RP (2006) Checklist of mammals in Ikh Nart Nature Reserve. Mongolian

Journal of Biological Sciences 4: 69–74. https://doi.org/10.22353/mjbs.2006.04.18

NSO (2018) National Statistics Office of Mongolia. http://www.en.nso.mn/. Accessed on: 2018-06-07

Nyhus PJ, McCarthy T, Mallon D (2016) Snow Leopards. In: McCarthy T, Mallon D (Eds) Biodiversity of the World: Conservation from Genes to Landscapes. Elsevier, Amsterdam, 409–417. https://doi.org/ 10.1016/C2014-0-01301-9

O'Brien TG (2011) Abundance, density and relative abundance: A conceptual framework. In: O'Connell AF, Nichols JD, K. Ullas Karanth K (Eds) Camera Traps in Animal Ecology: Methods and Analyses. Springer, Tokyo, 71–96. https://doi.org/10.1007/978-4-431-99495-4_6

O'Brien TG, Kinnaird MF, Wibisono HT (2003) Crouching tigers, hidden prey: Sumatran Tiger and prey populations in a tropical forest landscape. Animal Conservation 6: 131–139. https://doi.org/10.1017/S1367943003003172

Pardiñas UFJ, Myers P, León-Paniagua L, Ordôñez Garza N, Cook JA, Kryštufek B, Haslauer R, Bradley RD, Shenbrot GI, Patton JL (2017) Rodents II. Family Cricetidae. In: DE. Wilson, RA Mittermeier, TE Lacher (Eds) Handbook of the Mammals of the World. Vol. 7. Lynx Edicions, Barcelona, 283–284.

Potter LC, Brady CJ, Murphy BP (2018) Accuracy of identifications of mammal species from camera trap images: a northern Australian case study. Austral Ecology. https://doi.org/10.1111/aec.12681

R Development Core Team R (2018) R: A Language and Environment for Statistical Computing Team. R Foundation for Statistical Computing, Vienna, Austria. https://www.r-project.org/

Rovero F, Zimmermann F (2016) Camera trapping for Wildlife Research. Pelagic Publishing, Exeter, UK, 293 pp.

Rovero F, Marshall AR (2009) Camera trapping photographic rate as an index of density in forest ungulates. Journal of Applied Ecology 46: 1011–1017. https://doi.org/10.1111/j.1365-2664.2009.01705.x

Rovero F, Zimmermann F, Berzi D, Meek P (2013) "Which camera trap type and how many do I need?" A review of camera features and study designs for a range of wildlife research applications. Hystrix 24: 148–156. https://doi.org/10.4404/hystrix-24.2-8789

Rowcliffe JM, Carbone C (2008) Surveys using camera traps: are we looking to a brighter future? Animal Conservation 11: 185–186. https://doi.org/10.1111/j.1469-1795.2008.00180.x

Schai-Braun S, Hackländer K (2016) Lagomorphs and rodents I. Family Leporidae. In: Wilson DE, Mittermeier RA (Eds) Handbook of the Mammals of the World. Vol. 6. Lynx Edicions, Barcelona, 145–147.

Si X, Kays R, Ding P (2014) How long is enough to detect terrestrial animals? Estimating the minimum trapping effort on camera traps. PeerJ 2: e374. https://doi.org/10.7717/peerj.374

Smith AT, Xie Y, Hoffmann RS, Lunde D, MacKinnon J, Wilson DE, Wozencraft WC, Gemma F (2010) A Guide to the Mammals of China. Princeton University Press, Princeton, New Jersey, 576 pp.

Sollmann R, Mohamed A, Samejima H, Wilting A (2013) Risky business or simple solution—relative abundance indices from camera-trapping. Biological Conservation 159: 405–412. https://doi.org/10.1016/j.biocon.2012.12.025

Tobler MW, Carrillo-percastegui SE, Leite Pitman R, Mares R, Powell G (2008) Further notes on the analysis of mammal inventory data collected with camera traps. Animal Conservation 11: 187–189. https://doi.org/10.1111/j.1469-1795.2008.00181.x

Ward D (2010) The Biology of Deserts the Biology of Deserts. 2nd edition. Oxford University Press, Oxford, 370 pp. https://doi.org/10.1093/acprof:oso/9780199211470.001.0001

Von Wehrden H, Wesche K, Miehe G (2009) Plant communities of the southern Mongolian Gobi. Phytocoenologia 39: 331–376. https://doi.org/10.1127/0340-269X/2009/0039-0331

Weischet W, Endlicher W (2000) Regionale Klimatologie Teil 2. Die Alte Welt: Europa–Afrika–Asien. Teubner Verlag, Stuttgart, 626 pp.

Whittaker RJ, Araújo MB, Jepson P, Ladle RJ, Watson JEM, Willis KJ (2005) Conservation biogeography: Assessment and prospect. Diversity and Distributions 11: 3–23. https://doi.org/10.1111/j.1366-9516.2005.00143.x

Wilson DE, Reeder DM (Eds) (2005) Mammal Species of the World: a Taxonomic and Geographic Reference. 3rd Edition. Johns Hopkins University Press, Baltimore, Maryland, 2142 pp.